P7.4

SENSITIVITY OF SURFACE FLUXES, SOIL ENERGY, AND HYDROLOGY TO PARAMETERIZATION OF EVAPOTRANSPIRATION - A STUDY BASED ON THE ISLSCP INITIATIVE I DATA

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1. INTRODUCTION

Four different methods of estimating land-surface evapotranspiration are compared by running the schemes with the 1 deg. x 1 deg. ISLSCP Initiative I data that is based on an analysis of observations and models from January 1, 1987 through December 31, 1988 (Meeson *et al.*, 1995; Sellers *et al.*, 1995). The two classical methods by Thornthwaite and by Priestley-Taylor have been chosen because of their simplicity and extensive use in the past. These methods were used in conjunction with a Mintz formulation (Mintz and Walker, 1993) of the relationship between actual and potential evaporation. Additionally, we used Penman-Monteith, with different levels of approximation as shown in Pan (1990). Pan's scheme was implemented in earlier versions of models at NCEP. Our final method was with SSiB (Xue *et al.*, 1991), which has been used in the Goddard Laboratory for Atmospheres GCM and within our group's version of the GEOS model. The goal of this study is to delineate the differences in the surface hydrologic and energy interactions in different climatic regions on the world. We also hope to understand the advantage of using a physically more comprehensive scheme such as SSiB as opposed to a simple energy balance scheme in a GCM.

2. MODEL DESCRIPTIONS

The Thornthwaite (1948) parameterization uses a surface air temperature, which ideally should represent potential conditions, to calculate the potential evapotranspiration. The mean daily air temperature and number of daylight hours are used in an empirical relation for the daily potential evapotranspiration. The Priestley-Taylor (1972) parameterization gives potential evapotranspiration as a function of net radiation. The Penman (1948) - Monteith (1965) parameterization calculates the potential evapotranspiration as an energy balance between net radiation and energy fluxes into the ground and the air (as sensible and latent heat). The SSiB calculation of actual evapotranspiration combines detailed calculations of the rates of transpiration, bare soil evaporation, direct snow evaporation, and interception loss.

Three of these parameterizations provide the potential, not actual, evapotranspiration. Mintz and Walker (1993) related the potential to the actual evapotranspiration by a function of the normalized difference vegetation index (NDVI). This method, which is used with the Thornthwaite and Priestley-Taylor parameterizations, accounts for measured surface air temperatures that may not have been made under conditions of zero soil moisture stress. The Penman-Monteith parameterization uses a soil water stress factor for the second soil layer to relate potential to actual evapotranspiration.

Each of the various evapotranspiration parameterizations was run using the SSiB model soil hydrology. We used 3 soil levels with varying depths from the ISLSCP data. Soil and vegetation parameters (where applicable) were similarly held fixed between the separate runs. The SSiB model run used an hourly timestep, while the other model runs used a daily timestep. Only non-ice land points were considered, which yields a total of 14637 grid boxes.

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3. CONVERGENCE CRITERIA

Each of the four models were initialized with 0.75 soil wetness at all three soil layers. Using 1987 forcing conditions, the model was run from 1 Jan 1987 to 31 Dec 1987. The calculated soil wetness values (and soil temperatures and snow amounts, where applicable) at 31 Dec 1987 were then used back on 1 Jan 1987. The year 1987 was iterated 10 times for each evapotranspiration parameterization. The final 31 Dec 1987 conditions were then used as initial conditions for each respective full 2 year model run.

The soil moisture values at the end of each iteration were compared with the values before the iteration. A grid box was considered to have "converged" soil moisture at the end of 1987 when the total column soil moisture (in mm) was within 5 percent or 5 mm of the its value at the start of 1987. The total number of converged grid boxes at the end of each iteration for both the Penman-Monteith method and SSiB model runs is listed in Table 1.

Table 1: Converged Grid Boxes at the end of each Iteration - Out of 14637 Land Non-Ice Points.

Iteration	Penman-Monteith	SSiB
1	339	1408
2	7404	5344
3	9369	7309
4	10627	8952
5	11740	9700
6	12554	10081
7	13373	10473
8	14188	11081
9	14366	11619
10	14439	12126

Table 1 shows that the energy balance method of Penman-Monteith converges more rapidly than the SSiB method. After 10 years of iteration, 17 % of the grid boxes from the SSiB run did not converge. The majority of these grid cells are located in arid and/or cold regions.

4. SOIL MOISTURE

June-July-August mean root zone average soil wetness for both Penman-Monteith and SSiB are shown in Fig 1. Root zone soil wetness is the soil wetness down to the bottom of the second soil layer.

The SSiB model generally has wetter soil during the northern hemisphere summer as compared to the Penman-Monteith method. Areas where this is most noticeable are in eastern North America, Europe, China, and Brazil. The SSiB soil moisture values compare quite well to observations made in Illinois during this period (see Sud and Mocko, Paper 9.10, this volume), and not so well compared to observations in Russia. The Penman-Monteith values are generally lower when compared to these same observations.

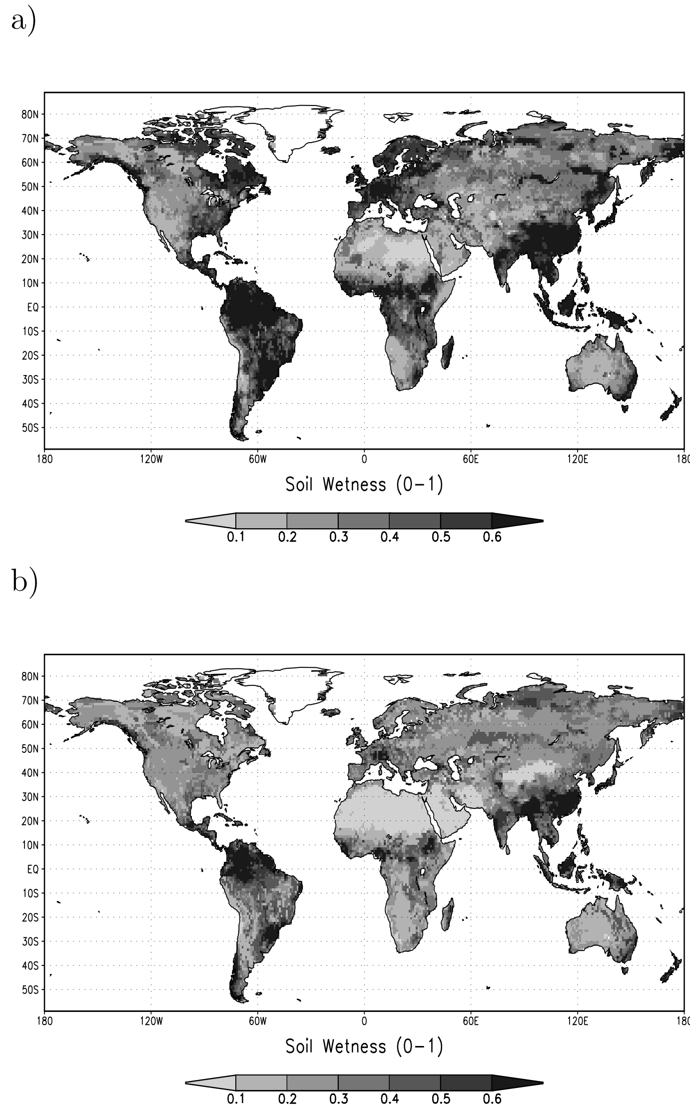
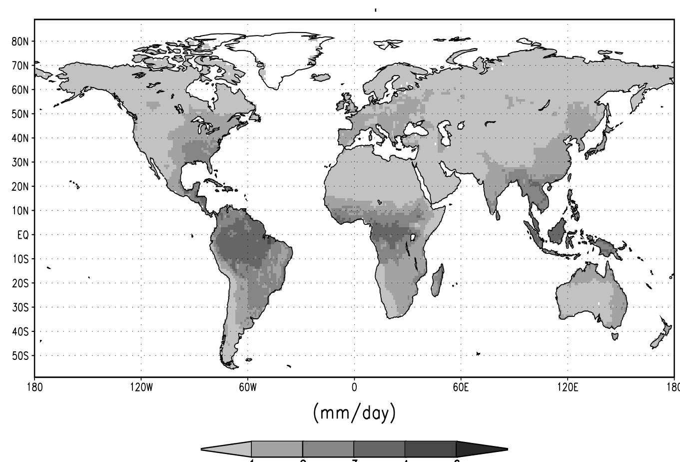


Figure 1: June-July-August Root Zone Soil Wetness (0–1) from: a) SSiB model; b) Penman-Monteith method.

5. ANNUAL EVAPOTRANSPIRATION

Mean evapotranspiration for 1987 and 1988 for both Penman-Monteith and SSiB are shown in Fig 2. The pattern between the two methods is similar, with high evapotranspiration in the tropics and low evapotranspiration in the deserts. The magnitudes also compare well, with two notable exceptions. The values in the tropical areas of South America, Africa, and Indonesia are much larger (nearly 2 mm/day averaged annually) for the Penman-Monteith method as compared to SSiB results. These areas are dominated by broadleaf evergreen forest. On average, this vegetation type over the globe gives over 38 % more evapotranspiration from Penman-Monteith than from SSiB. The reason for this is the daily timestep of the Penman-Monteith method produces larger evapotranspiration than should be expected over nighttime hours.

a)



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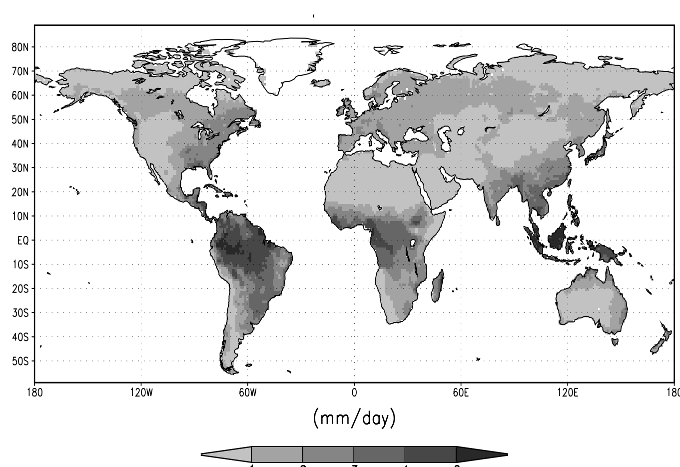

Figure 2: Mean Evaporation for 1987 and 1988 from: a) SSiB model; b) Penman-Monteith method.

Consequently, the Penman-Monteith method removes water than from the soil more quickly, as well as leads to lower soil moisture values after several iterations as compared to SSiB. For lower soil moisture values, the 5 percent convergence criteria is less stringent and leads to quicker convergence in the Penman-Monteith method.

The other exception to the comparison of the evapotranspiration maps is in North America and Russia between 50 and 65 N. These areas contain high-latitude deciduous forest and woodland. Here also, the Penman-Monteith method produces larger evapotranspiration values than SSiB. Comparison of sensible and latent heat fluxes with observations will bring insight into which method does a better job, but the method's effect on soil moisture compared to observations is better handled using SSiB.

6. UNITED STATES TRANSECTS

We now examine in greater detail the time evolution of certain areas of the globe through the use of a time-longitude transect. Fig 3 shows the pattern of precipitation, and Fig 4 shows evaporation, precipitation minus evaporation (P - E), and soil moisture for 38 N across varying longitude along 120 to 80 W. The central United States experienced a significant drought in the spring of 1988. The SSiB model reproduces this feature, especially in the plot of precipitation minus evaporation. The Penman-Monteith method has generally lower soil moisture values than from SSiB during the entire 2 years, and the drought, while present, is not as obvious and does not last as long. A dramatic drying of the soil within the SSiB model in July 1988 compared to July 1987 also demonstrates an effect of this drought.

7. CONCLUSIONS

We have found that an energy balance method of determining the evapotranspiration can produce larger latent heat flux values in tropical and high-latitude forests as compared to the SSiB model. These large evapotranspiration values result in drier soil moisture conditions in the tropics and high-latitude areas in an energy balance method than from SSiB. Comparison of soil moisture values from SSiB to observations is better than when the observations are compared to energy balance values. Additional results and figures from the other two evapotranspiration methods will be shown at the conference.

8. ACKNOWLEDGMENTS

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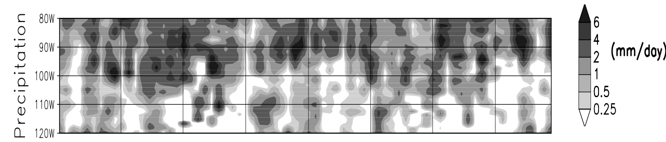

Figure 3: Time-longitude transect of precipitation along 38 N across the United States.

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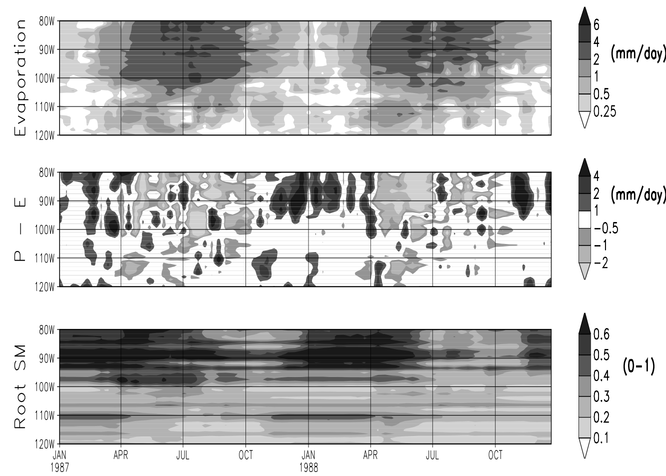

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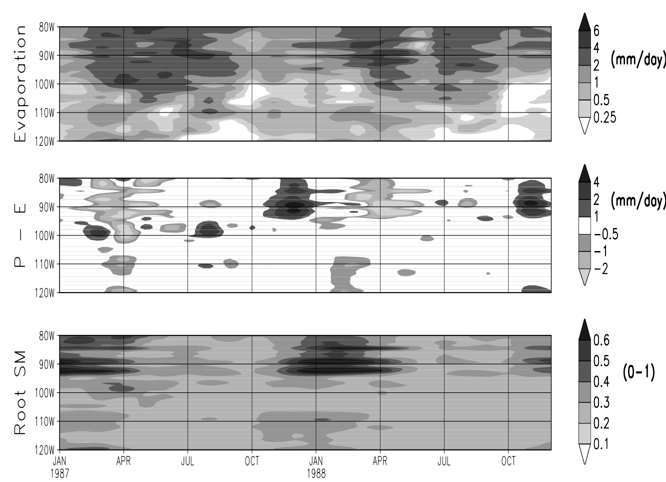

Figure 4: Two sets of time-longitude transects along 38 N. Shown are evaporation (top), precipitation - evaporation (middle), and root zone soil wetness (bottom) from: a) SSiB model; b) Penman-Monteith method.